

# Integrated Optic and Fiber Optic Devices for Communication and Sensor Networks

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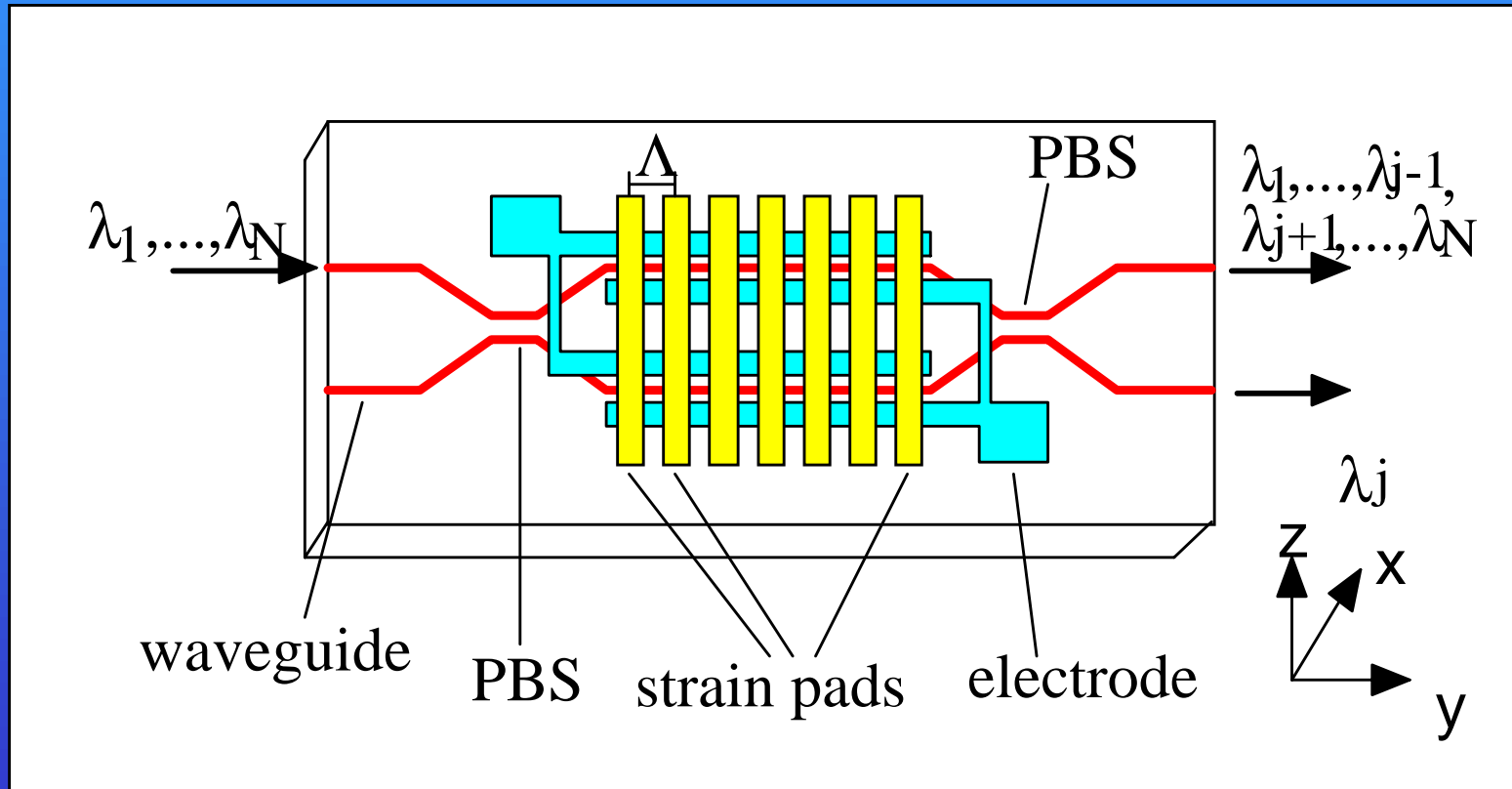
# WDM-Related Research at Texas A&M University

- Electrooptic Tunable Filters for Fiber Optic Networks
- Slow Wave Electrooptic Modulators for Reduced Microwave Drive Power and Improved Response Linearity
- Fiber Fabry-Perot Interferometer Sensors for Measuring Pressure, Temperature, and Strain

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# Electrooptic Tunable Filter (EOTF)



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# Electrooptic Tunable Filter Development Objective

Develop filter to meet requirements of dense wavelength multiplexing:

- Polarization independence

- 50 or 100 GHz channel spacing

- Submicrosecond tuning

- $< 3$  dB insertion loss

- $< -25$  dB interchannel crosstalk

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# Electrooptic Tunable Filter Development

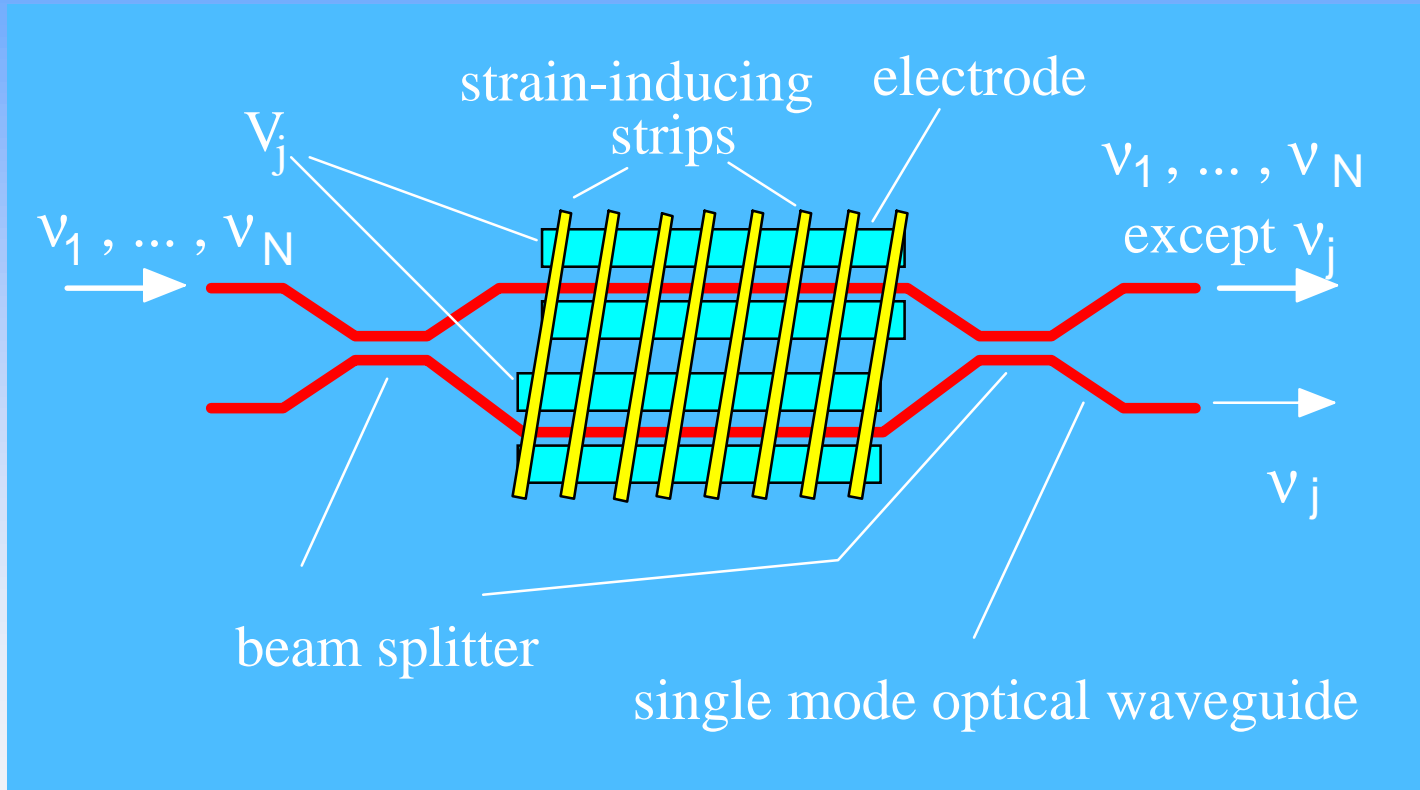
## Technical Approach

- Substrate: lithium niobate
- Waveguide structure: Mach-Zehnder interferometer; polarizing beam splitters not required
- Polarization coupling: periodic, strain-inducing silicon dioxide film

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# New 4- Port EOTF Design

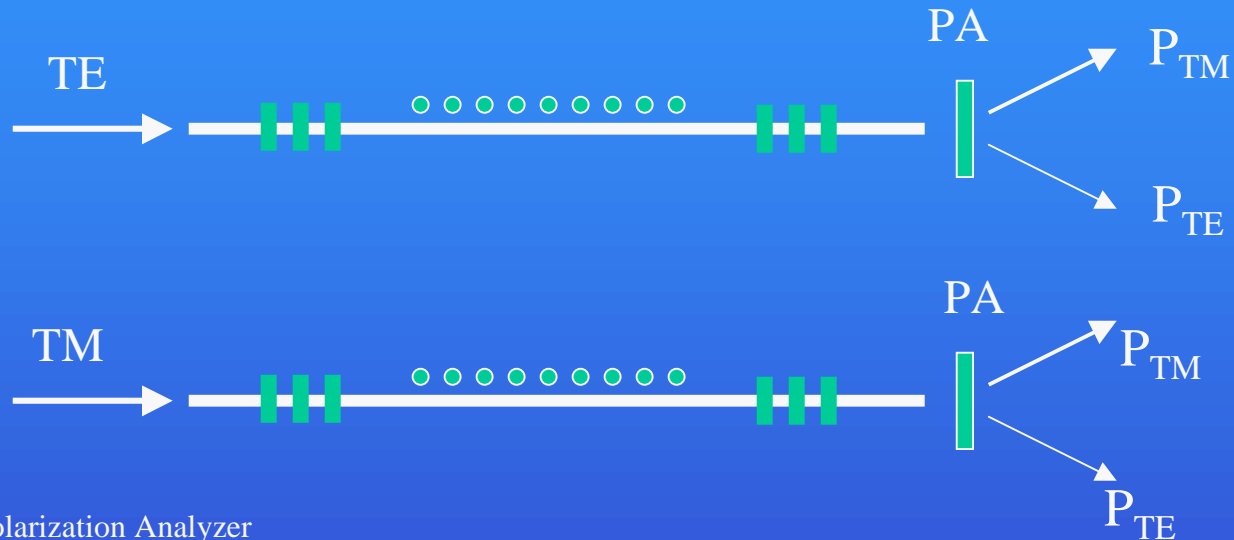


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# TE/TM Mode Conversion

## Channel Waveguides with Grating



Conversion Efficiency

$$\eta_{TE(TM)} = \frac{P_{TM(TE)}}{P_{TM} + P_{TE}}$$

Conversion Bandwidth

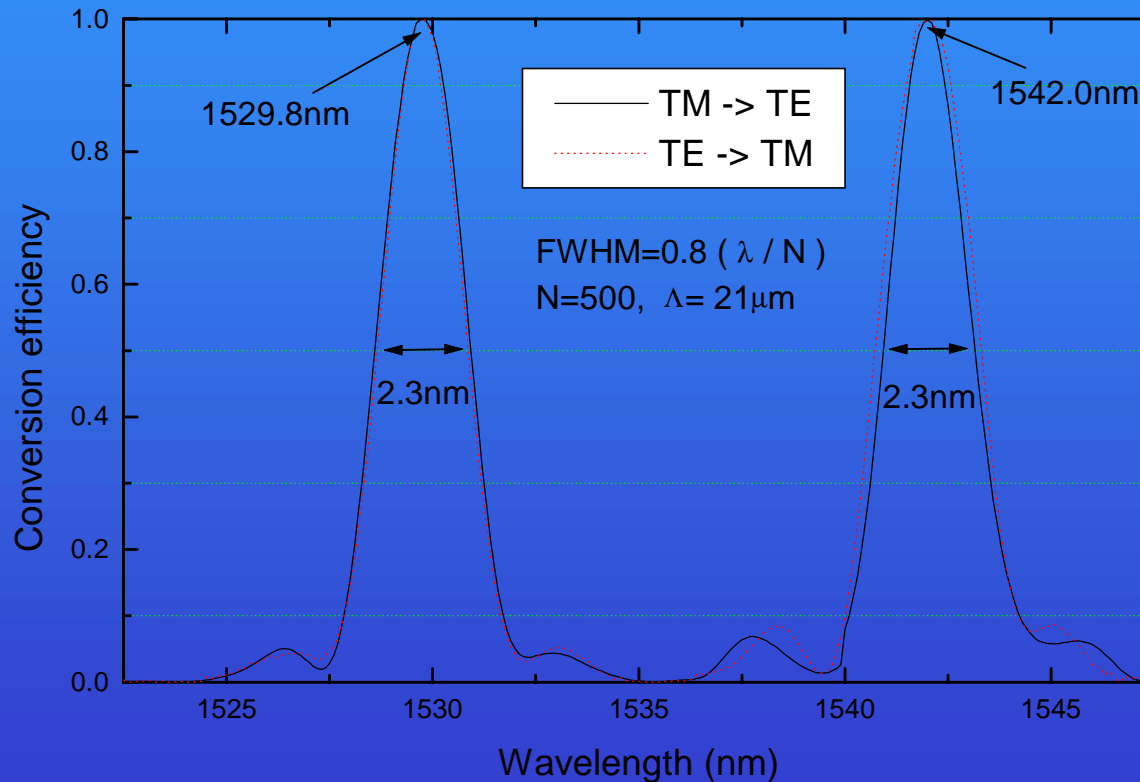
$$FWHM = 0.8 \frac{\lambda}{N}$$

N: number of grating periods

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# Mode Conversion Efficiency and Thermal Tuning

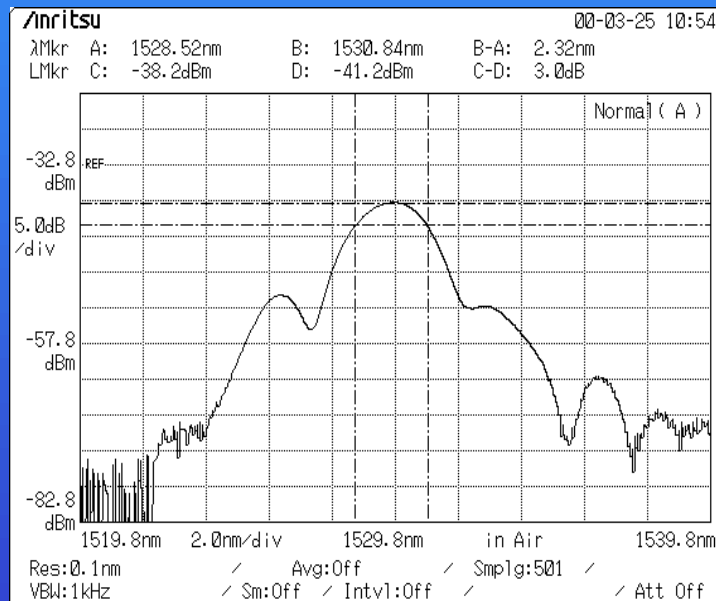


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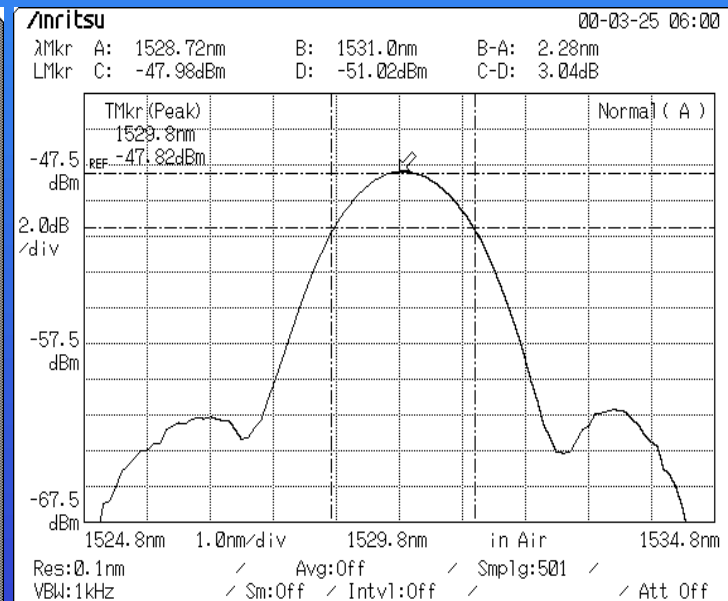
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# FWHM of Filter

TM to TE, FWHM=2.32nm



TE to TM, FWHM=2.28nm

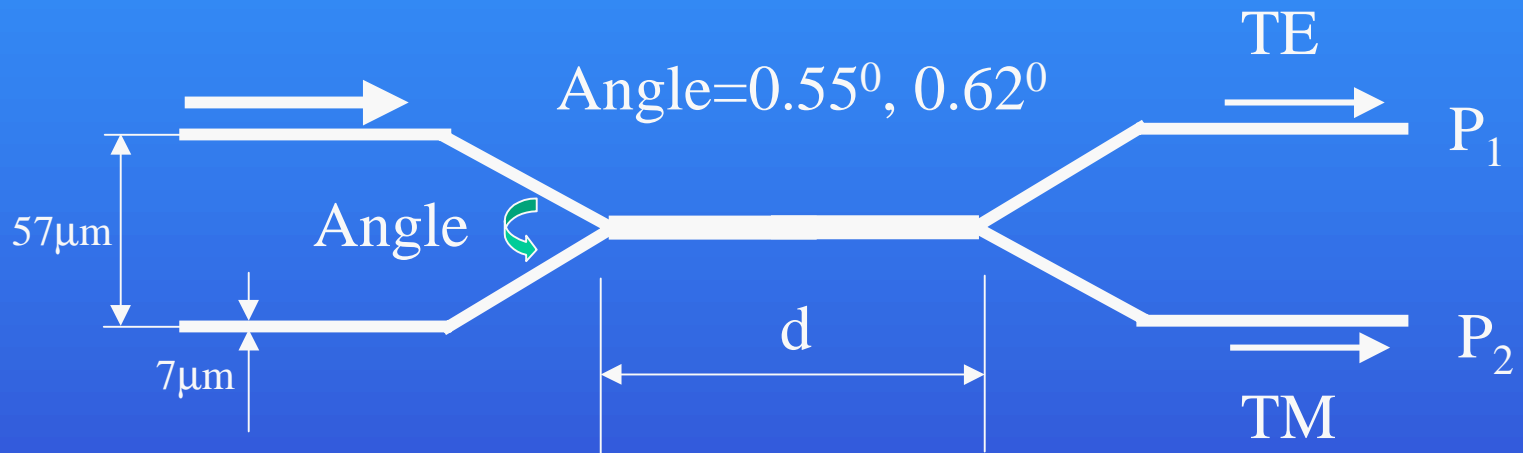


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# Polarization Splitter(Te/TM splitter) (Ti: LiNbO<sub>3</sub>)

Principle: Two Mode Interference (TMI)



ER: Extinction Ratio

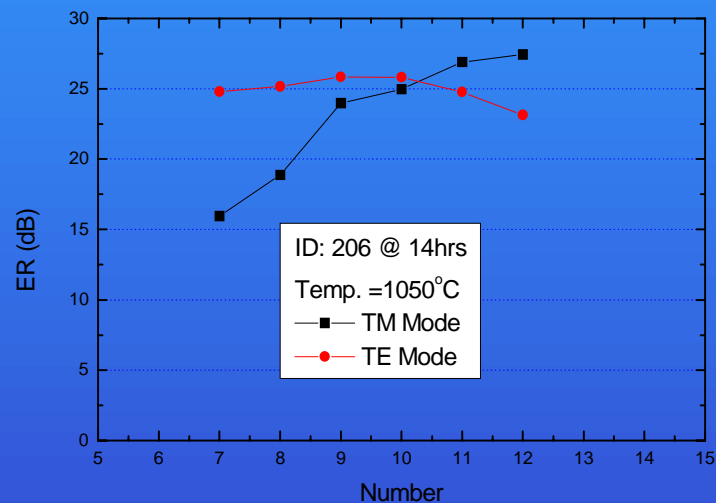
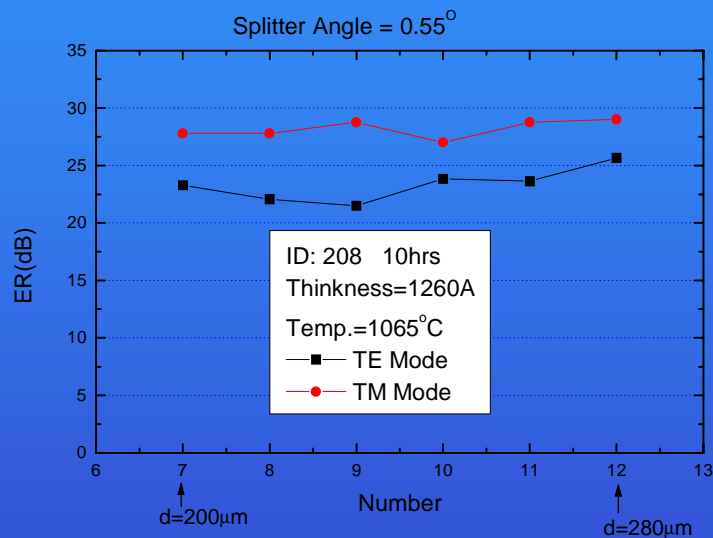
TM Mode: 
$$ER = -10\log\left(\frac{P_1^{TM}}{P_1^{TM} + P_2^{TM}}\right)$$

TE Mode: 
$$ER = -10\log\left(\frac{P_2^{TE}}{P_1^{TE} + P_2^{TE}}\right)$$

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# Experimental Results of Splitter



$$ER[dB] = 10\log\left(\frac{P_{TE(TM)}}{P_{TM(TE)}}\right)$$

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# EOTF Summary

- High ( $>99.5\%$ ) polarization conversion was achieved in channel waveguides.
- High ( $> 25$  dB) extinction ratio has been obtained in polarizing beam splitters.
- New EOTF design with relaxed beam splitter requirements has been proposed.
- Completion of first four-port EOTFs is planned for Dec. 2000.

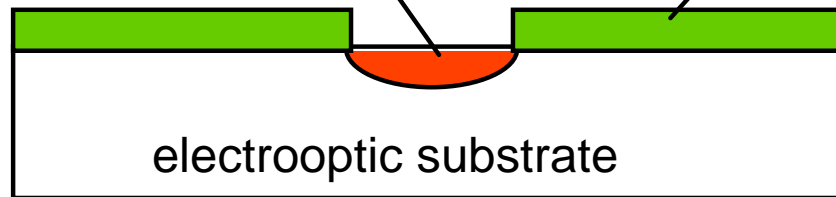
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# Low-Voltage SBN Modulator

strain-induced waveguide

electrode



substrate material: SBN:60

waveguide loss:  $< 0.3$  dB/cm

voltage-length product: 0.25 V-cm

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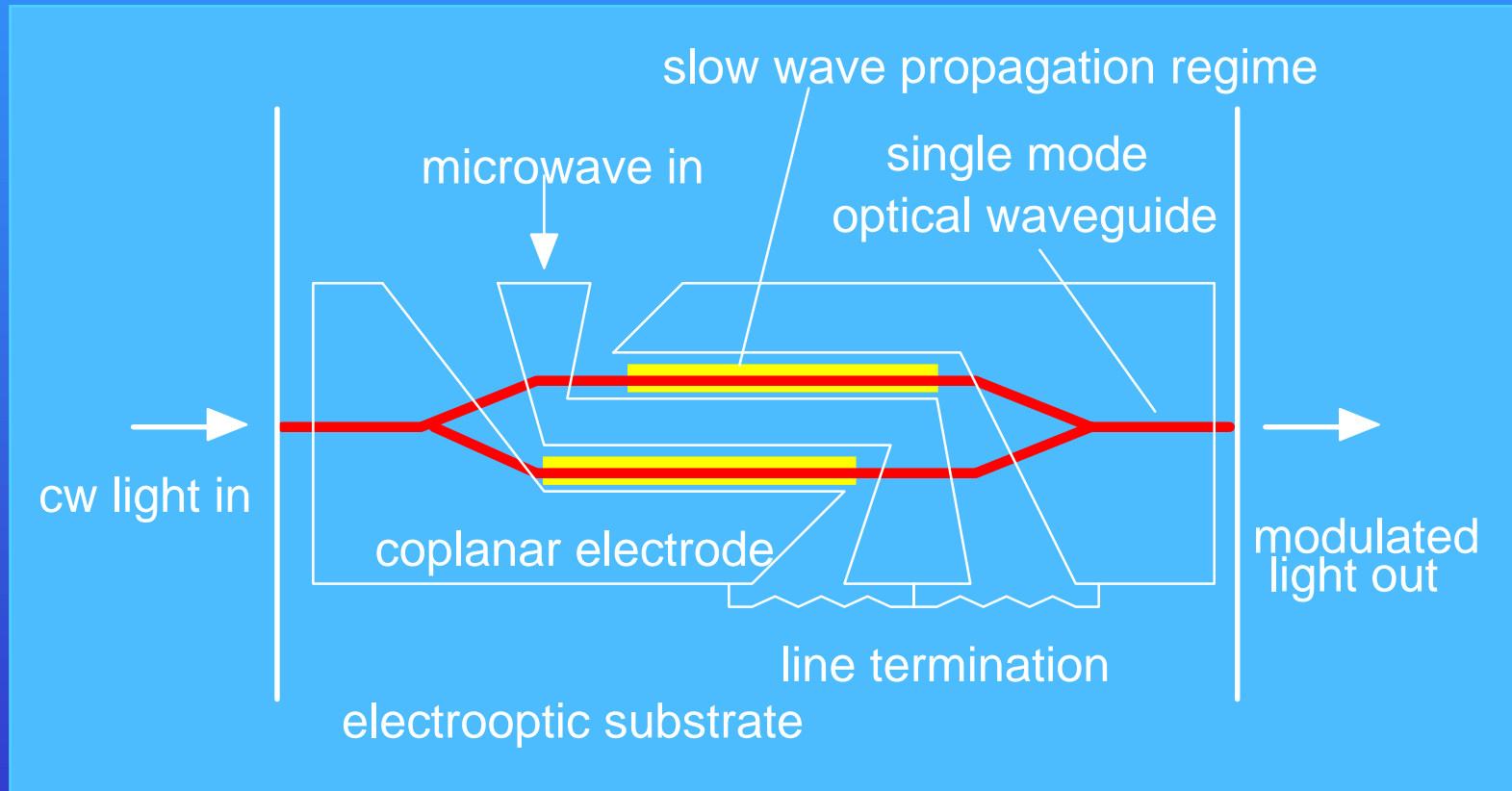
# Summary of SBN Results

- Low-loss (0.3 dB/cm) strain-induced waveguides
- Low optical damage susceptibility ( $\ll$  lithium niobate,  $<$  lithium tantalate)
- GHz modulation demonstrated
- Record low voltage-length product (0.25 V-cm)

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# Slow Wave Electrooptic Light Modulator



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# Slow Wave Electrooptic Modulator

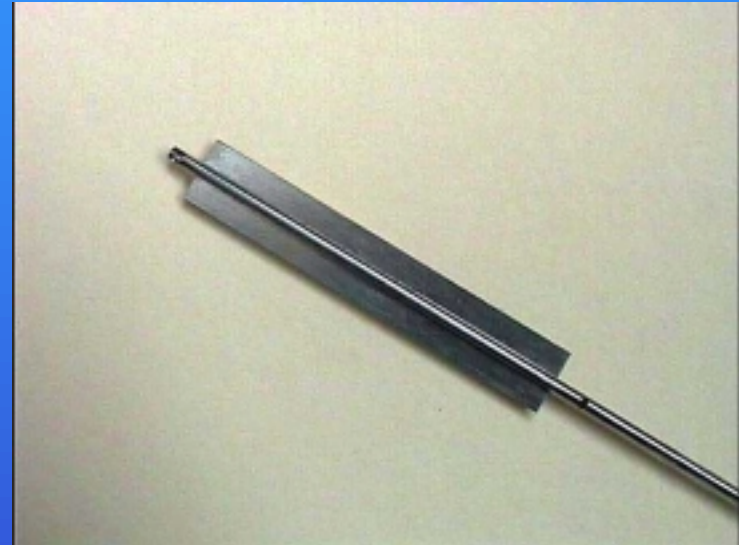
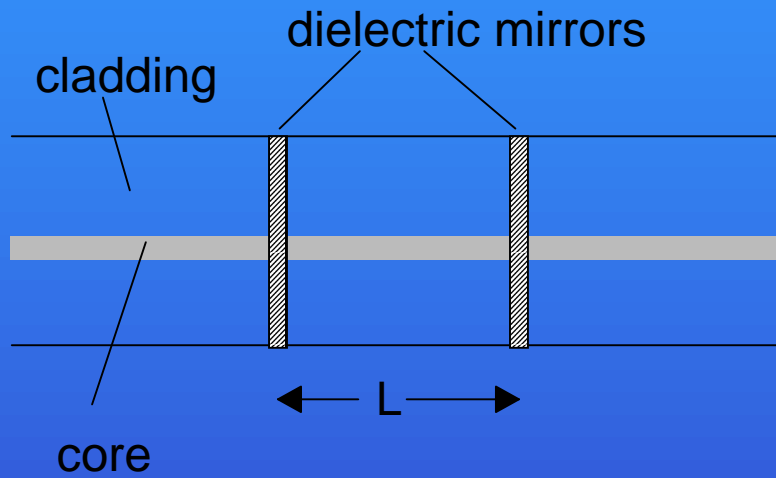
## Potential Benefits

- Orders-of-magnitude reduction in electrical drive power
- Improved response linearity and SFDR

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# Fiber Sensors for WDM Networks



Fiber Fabry Perot  
Interferometer (FFPI)

FFPI Strain  
Sensor

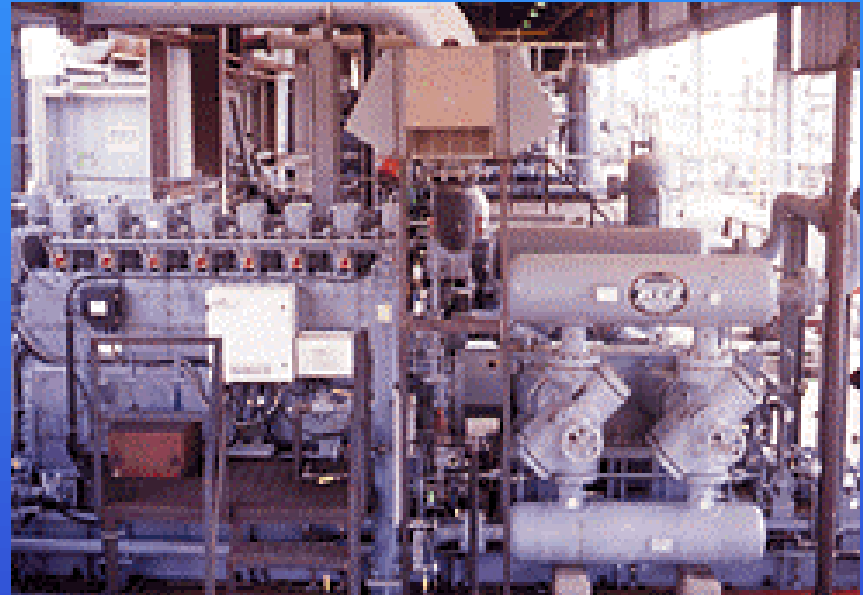
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# Fiber Sensors for WDM Networks



FFPI Pressure Sensor



Engine Instrumented with  
FFPI Pressure Sensors

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# Demonstrated FFPI Sensor Measurands

- Pressure (static, acoustic, ultrasonic)
- Temperature
- Strain
- Magnetic field
- Acceleration
- Flow rate

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# FFPI Sensors for WDM Networks

- FFPI sensors can operate at high temperatures (to 1200 K), high pressures ( $> 10$  kpsi) and high speeds ( $> 50$  kHz)
- Readout using white light interferometry (WLI) provides absolute parameter measurement (dc performance) and multiplexing of many sensors on one fiber
- FFPI sensors are produced by Fiber Dynamics, Bryan, TX

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# Conclusion

Electrooptic tunable filters, slow wave modulators, and FFPI sensors are emerging technologies with considerable potential for application in military and commercial WDM networks.

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